Investigation of the vibrational stability of synchrotron X-Ray optics using a differential interferometer

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BARCELONA

HELMHOLTZ GEMEINSCHAFT

DESY

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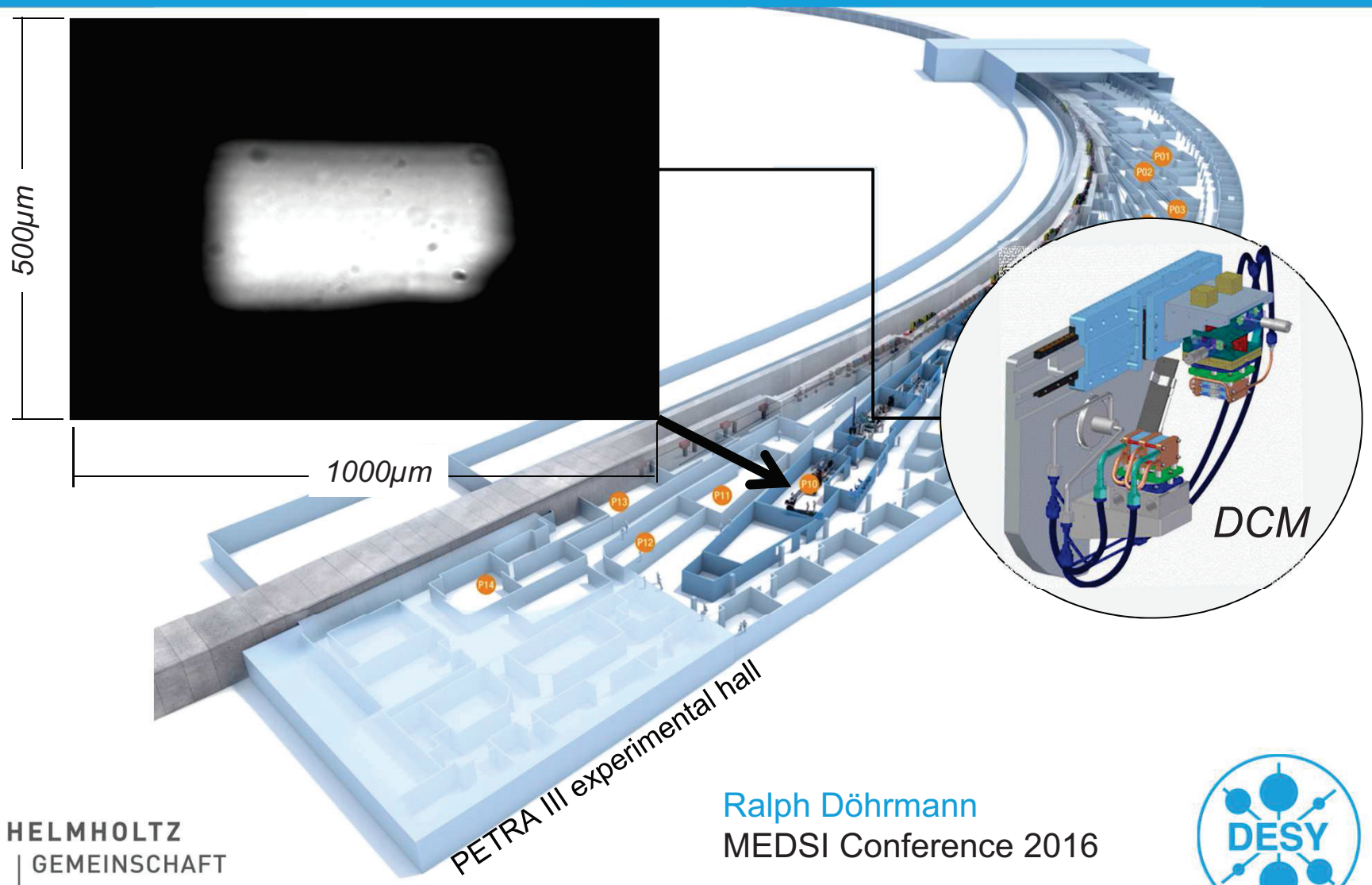

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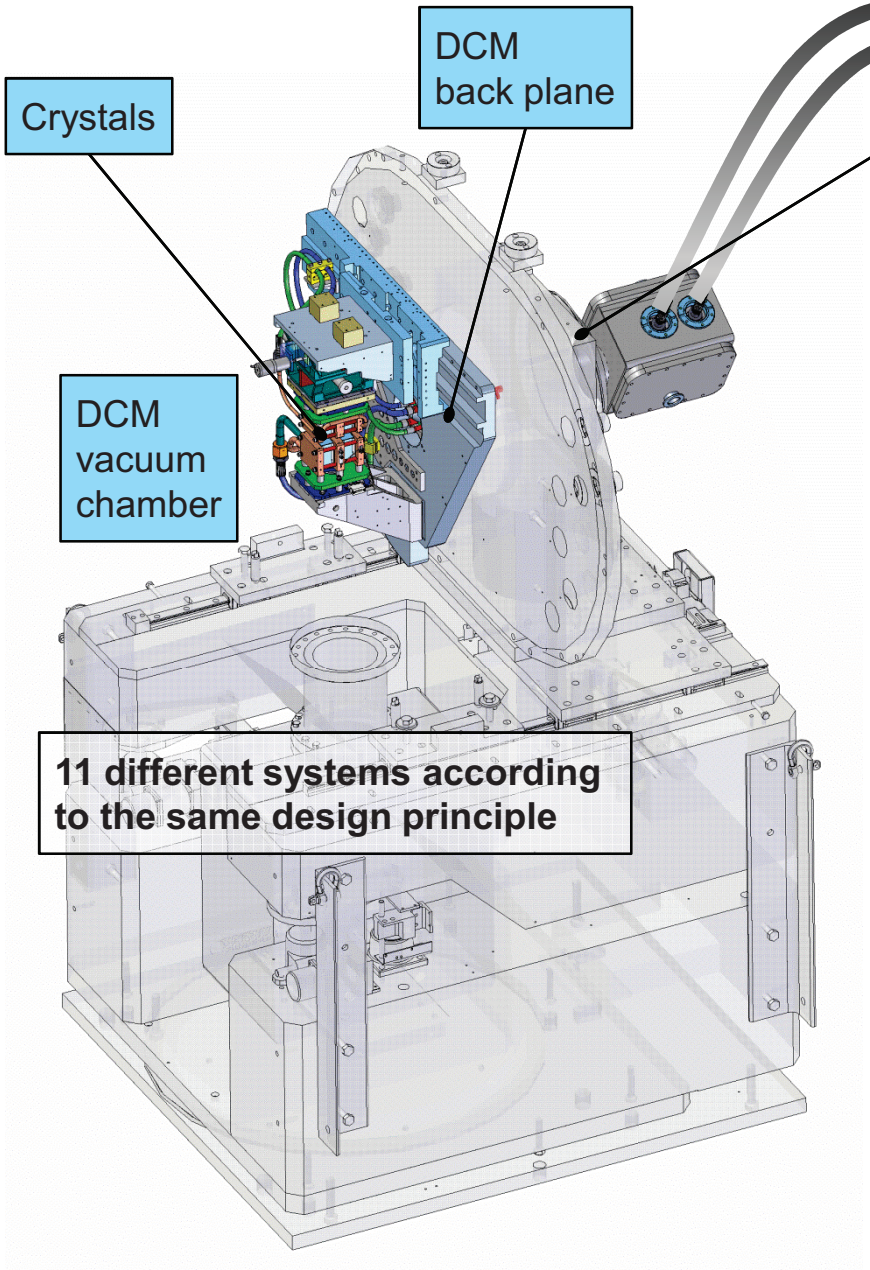
MEDSI Conference 2016

DESY

Outlook

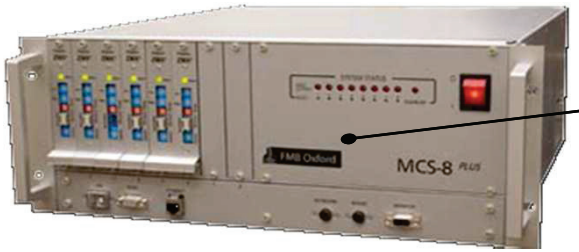
- PETRA III Cryo –cooled double crystal monochromators (DCM)
- What kind of vibrations do we have and why are they bad?
- How to measure and assess the vibrations
- Systematic investigations at the DCMs
- Results and design improvements

PETRA III cryo-cooled Double Crystal Monochromator (DCM)



LN_2 transfer tubes

Cryo-pump



Bragg axis motor-control system

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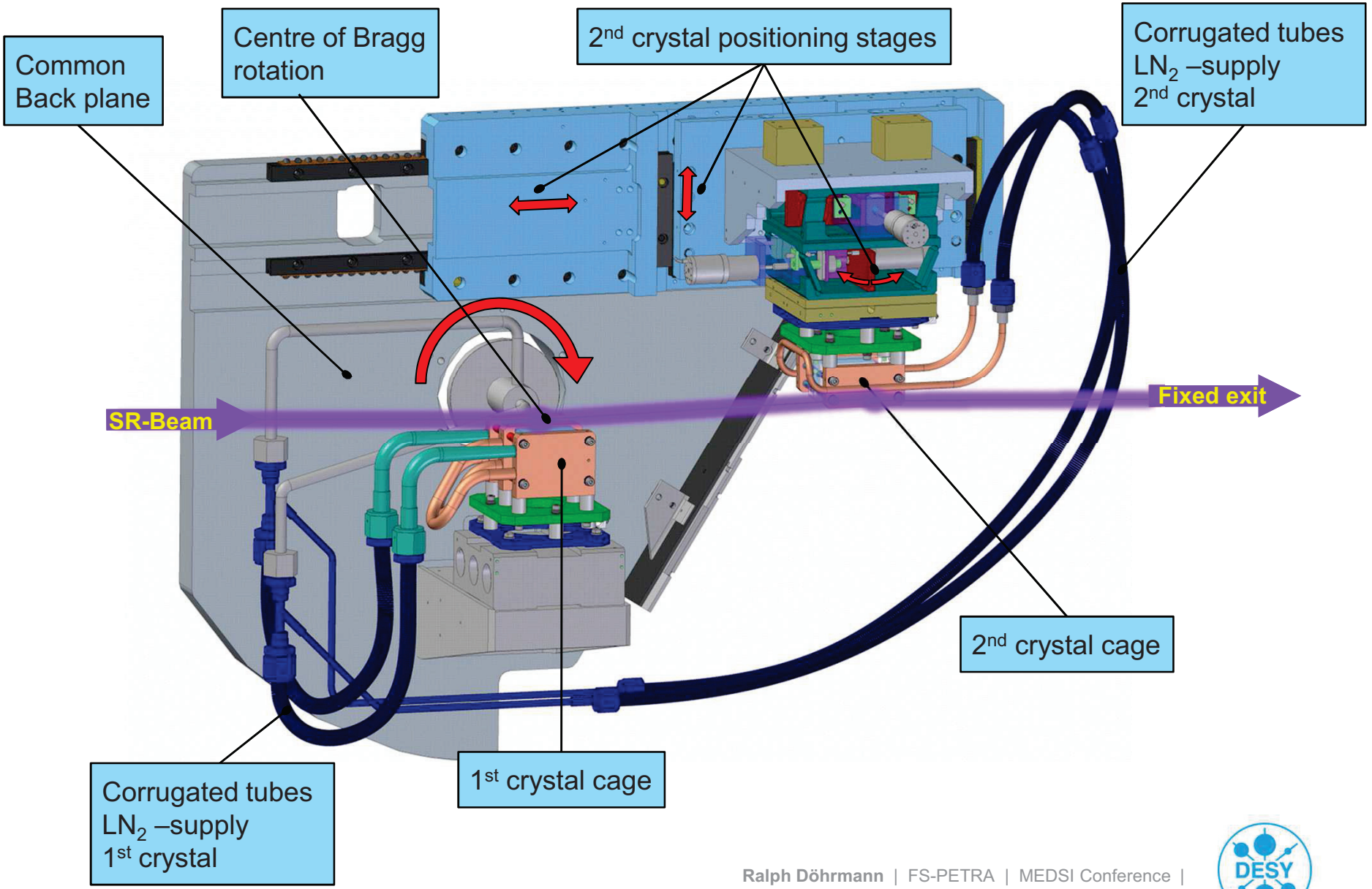
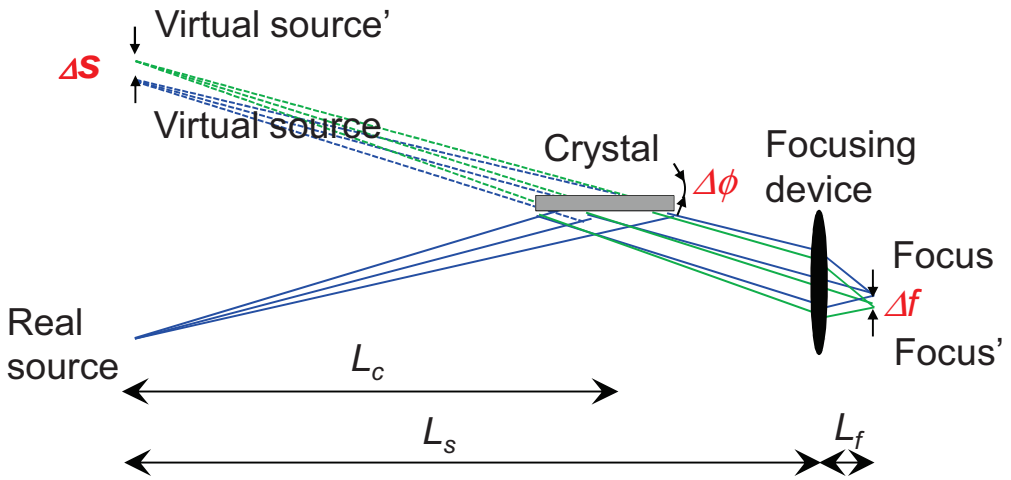
Initial state of the DCM



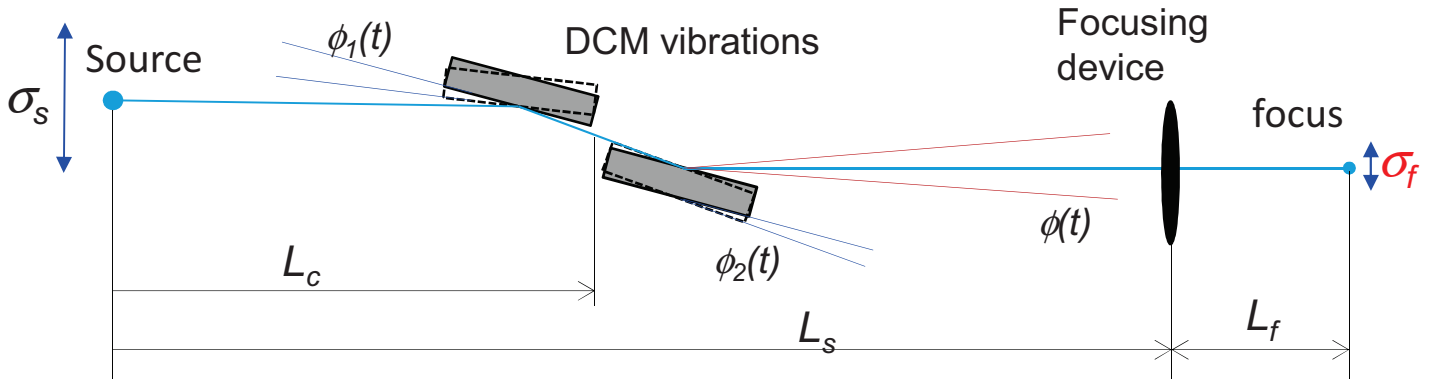
Vibrations and the effect on the beam quality

Effect of crystal vibrations



Leads to broadening due to the movement of the virtual source (Δs)

Effect of relative movements of beamline optics

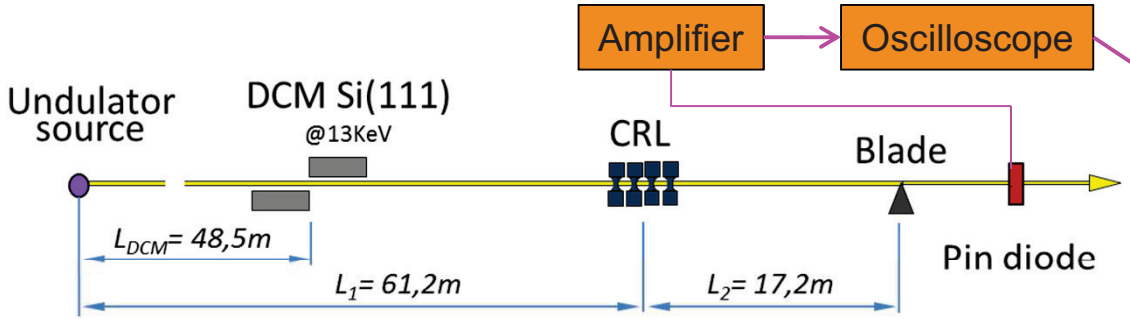


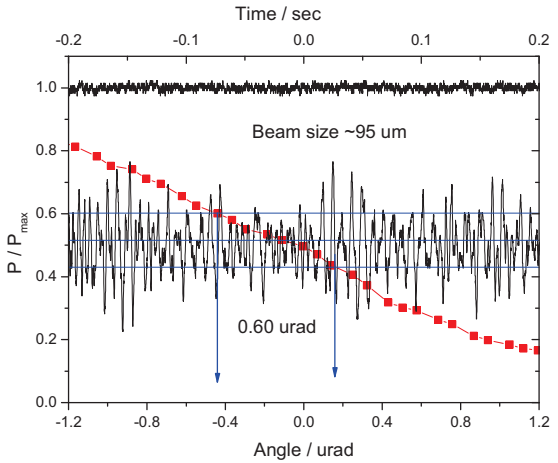
Leads to broadening due to movement of beam and focus position (σ_f)

Vibrations measurements using the x-ray beam

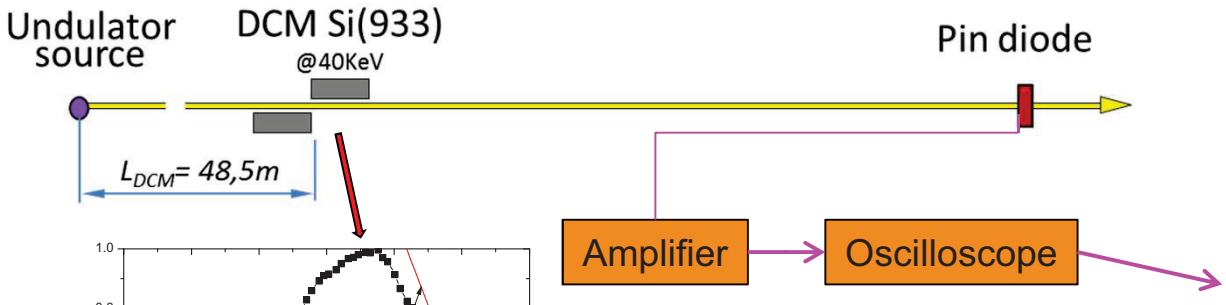
- How can we measure and analyze the beam vibrations
- Reproducible methods are required

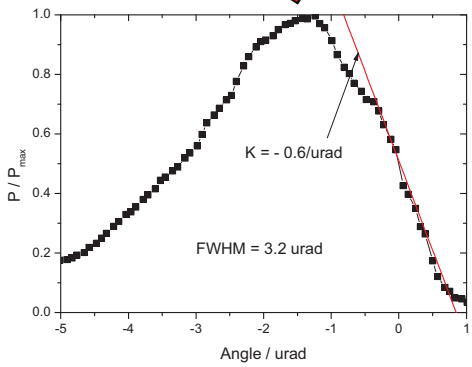
Focused beam at knife edge



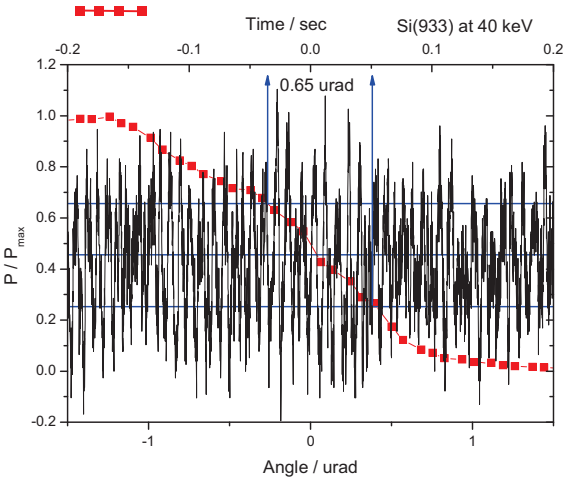


Full beam at slope of rocking curve



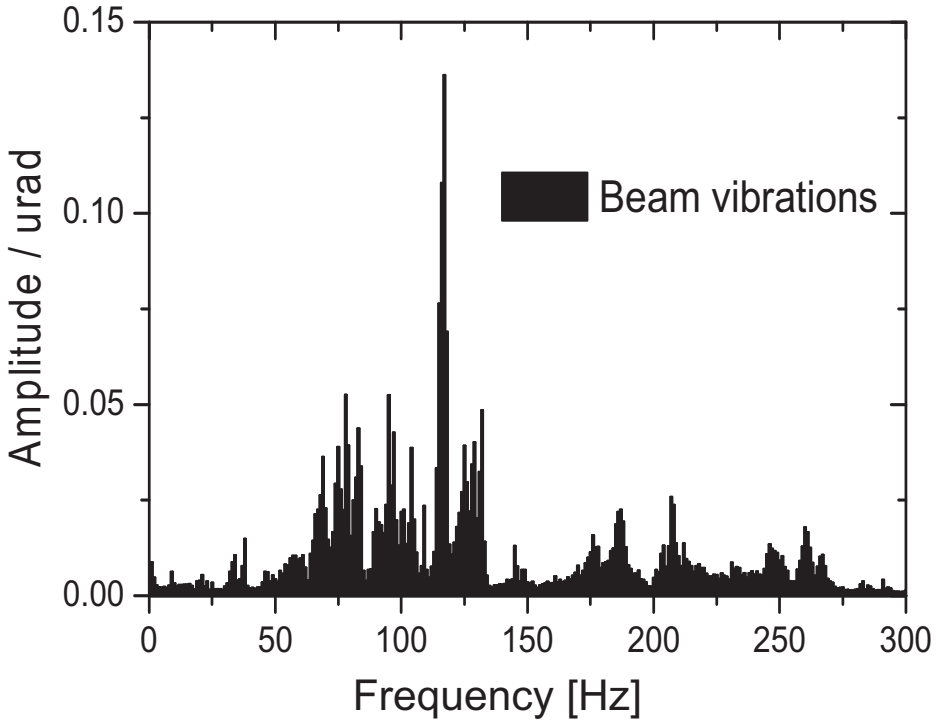


Pitch scan 2nd crystal

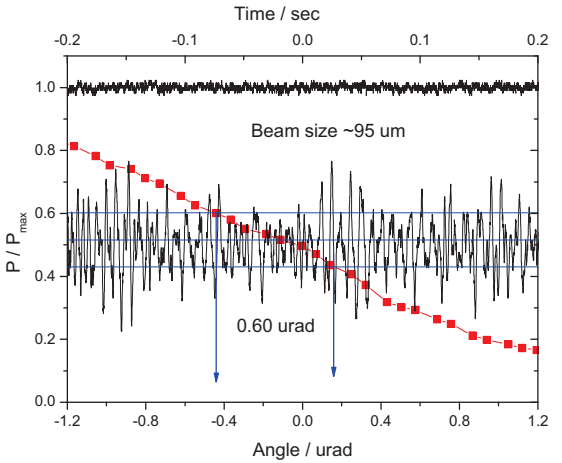


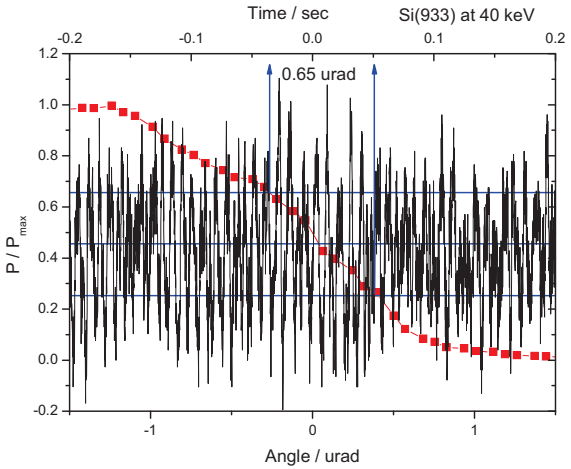
Vibrations measurements using the x-ray beam

- Fourier transformation to separate the vibration contributions



$$\sigma^2 = \sum_{i=1}^{N} {c_i}^2$$





- Both methods produced comparable results.

Vibrations measurements using the x-ray beam

Methods working well to define vibration behavior of the beam

Only limited access to the installed DCM during the measurement periods.

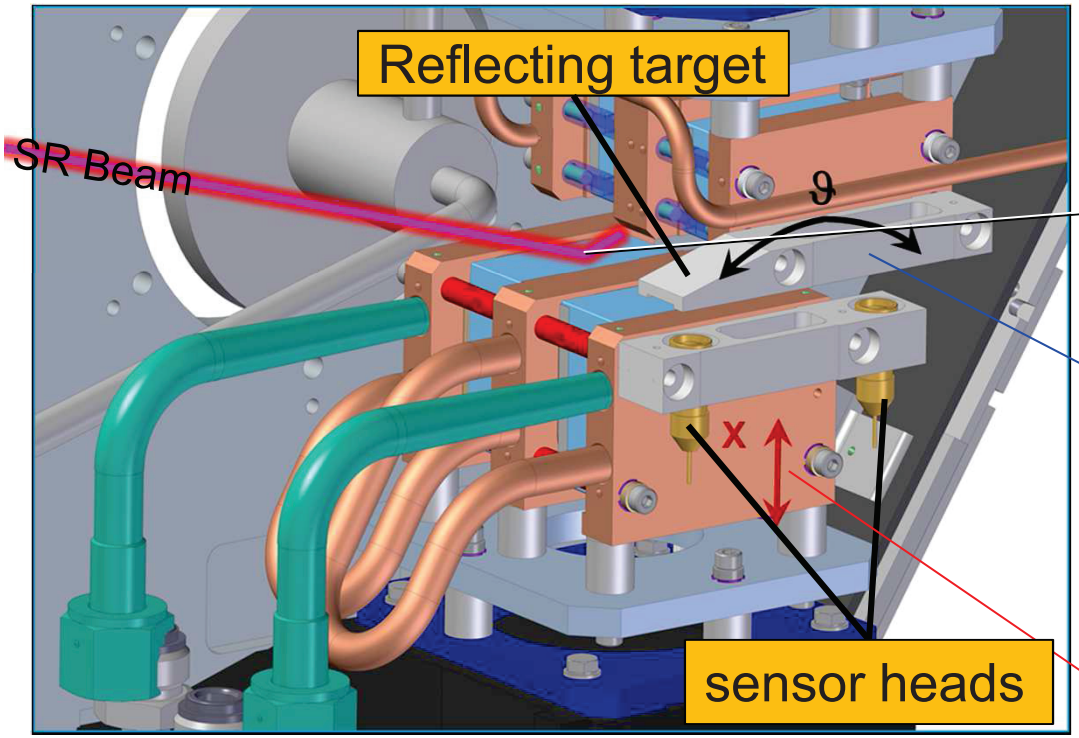
Perform vibration measurements, without synchrotron beam

Requires new methods to measure the DCM vibrations

Perform test- experiments under operating conditions

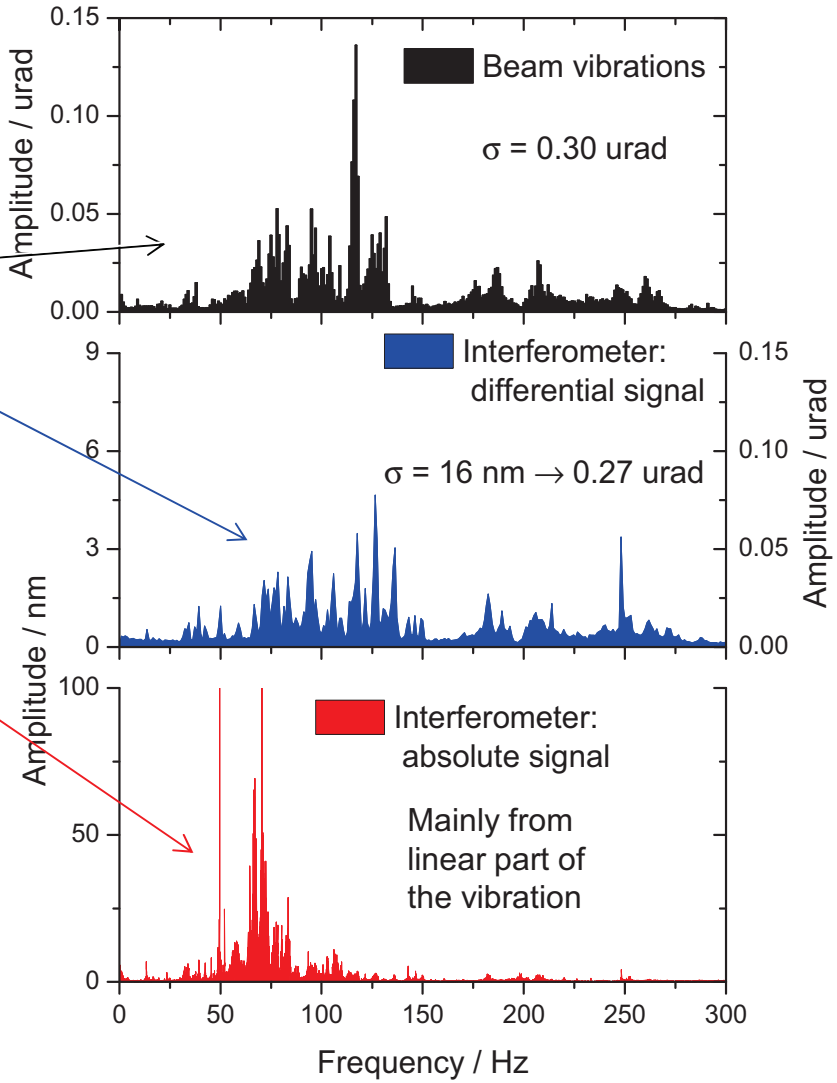
Comparability of DCM vibration and beam vibration is necessary.

Vibrations measurements using a differential interferometer



Laser interferometer

Working distance	0-400 mm
Sensitivity	25 pm
Repeatability	2 nm
Bandwidth	10 MHz

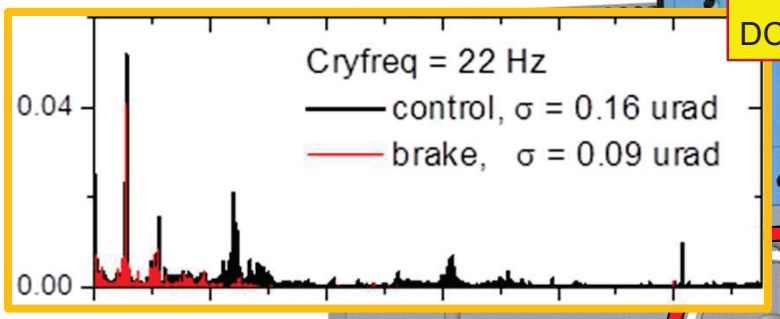


Performed modifications in the DCM

Possible vibration sources in the Cryo -system

Possible reasons for relative movements of the crystals

Other sources of vibration

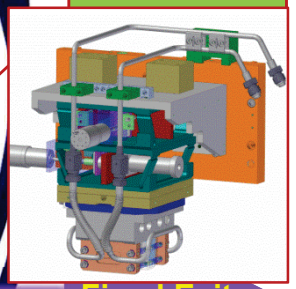


Servo-controlled DCM compared to DCM with applied brake

Low stiffness

Replaced by rigid aluminum blocks (only for tests)

Connection in critical direction

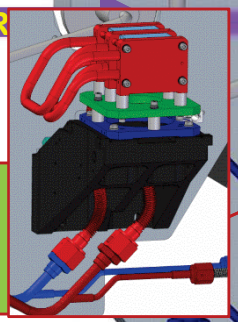


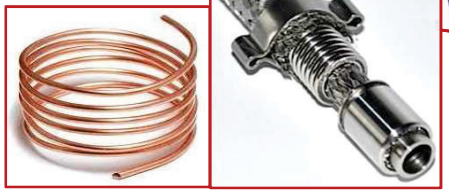
Servo motor for Bragg - Rotation ???

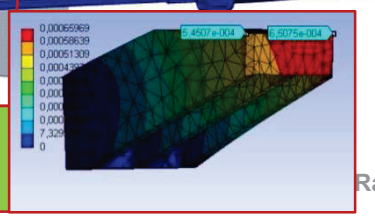
In coming SR

Fixed Exit

Connection in critical direction







Low stiffness

tubes (generate turbulent flow)

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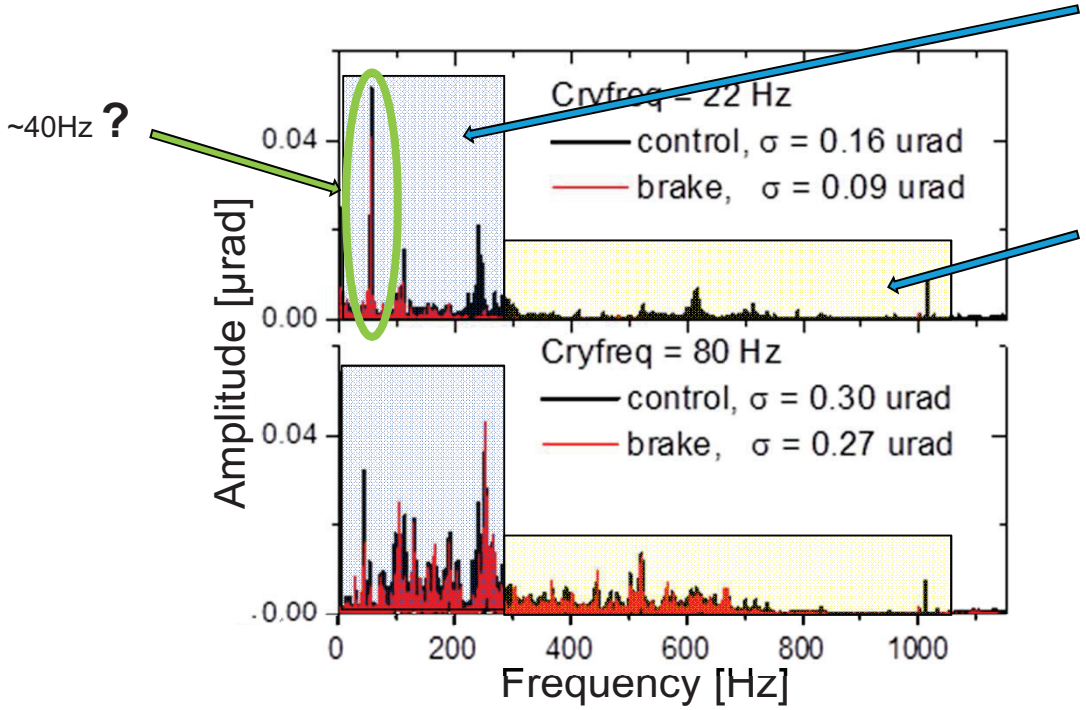
What we learned from these investigations

- Many small improvements but no real breakthrough.
- One source of vibration could be identified



Mainly due to LN2 system

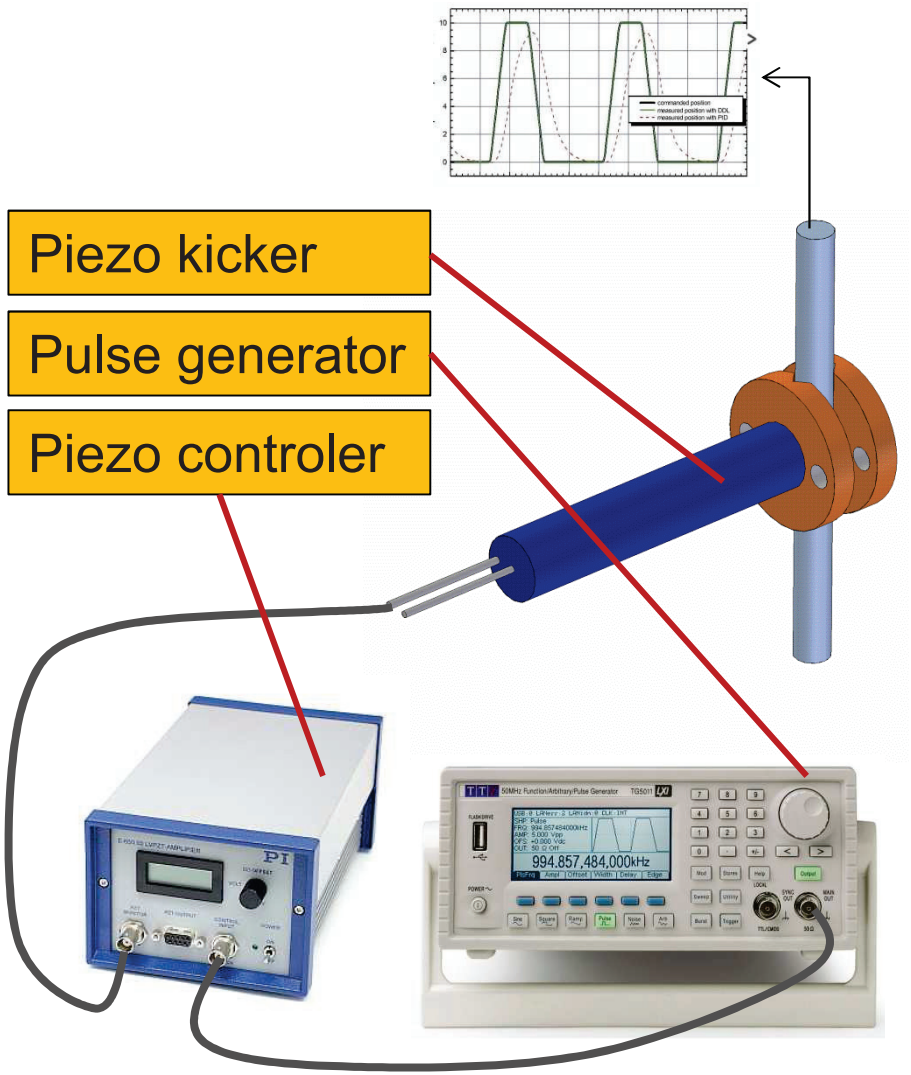
Mainly due to the Bragg axis control

- The actual cause of the vibrations due to LN_2 system was still unclear.

→ **So we had to find further investigation methods**

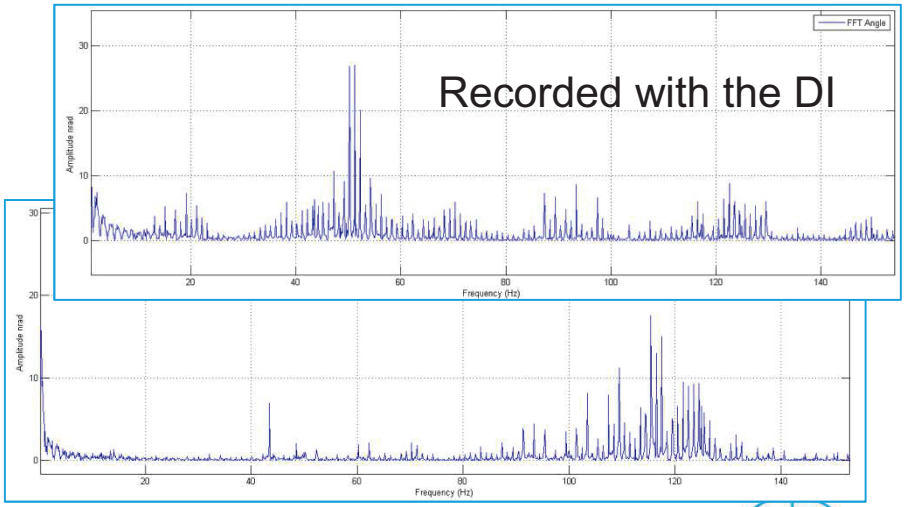
Further investigations at the DCMs with a micro- resonator

> Analysis of individual components through specific excitation of the natural frequencies due to micro- resonator.



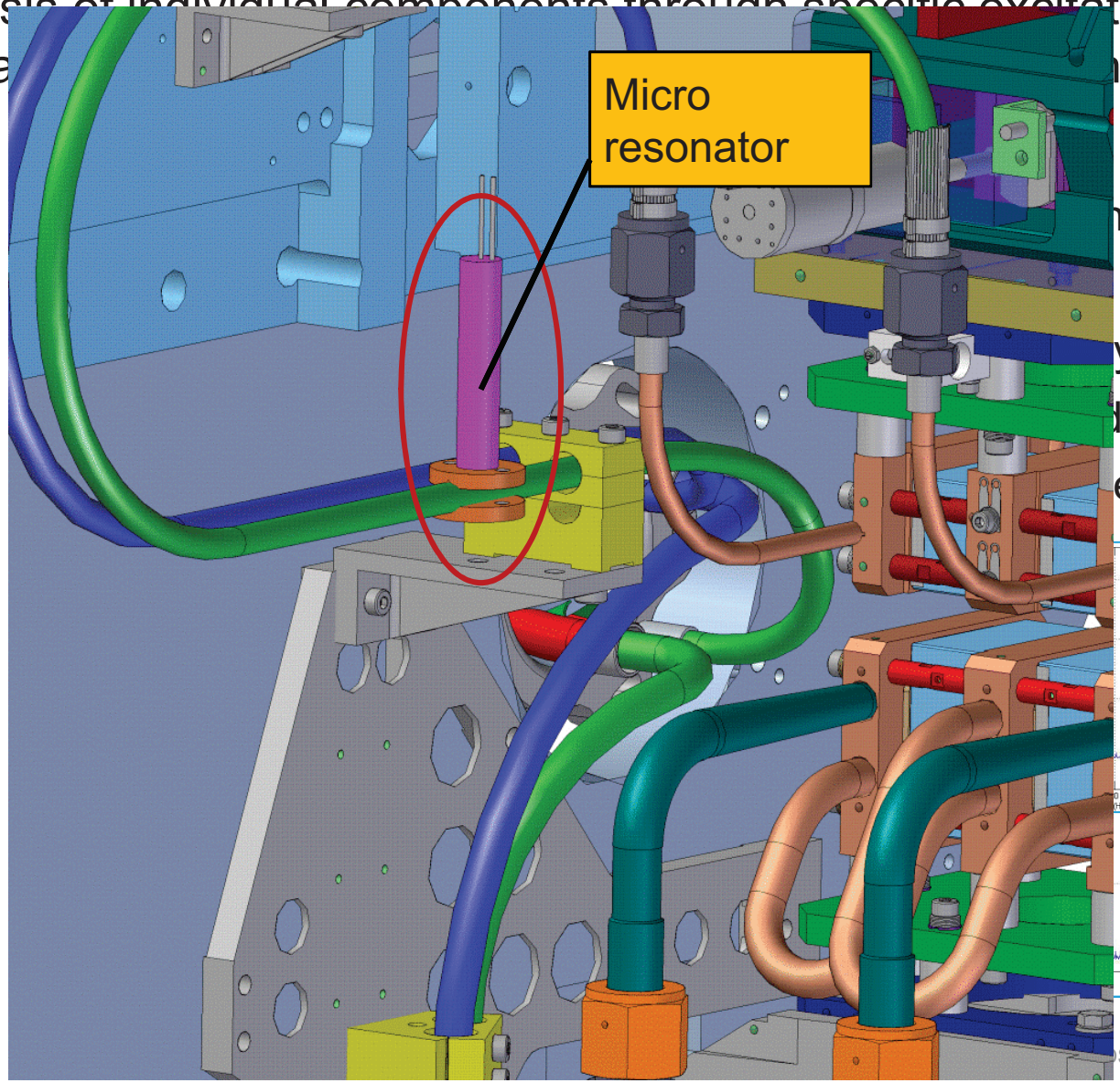
Advantages:

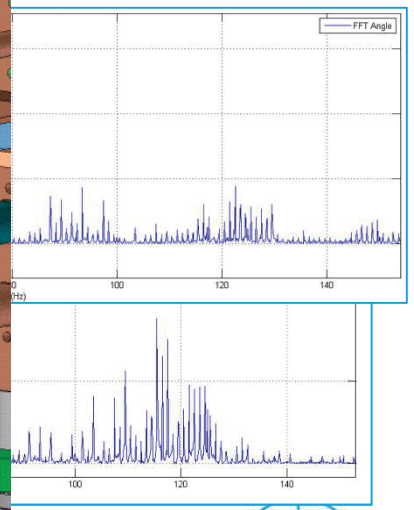
- Selective stimulation of components
- Uniform excitation
- Adjustable frequency
- Minor sensitivity to disruptions
- All natural frequencies visible



Further Investigations at the DCM

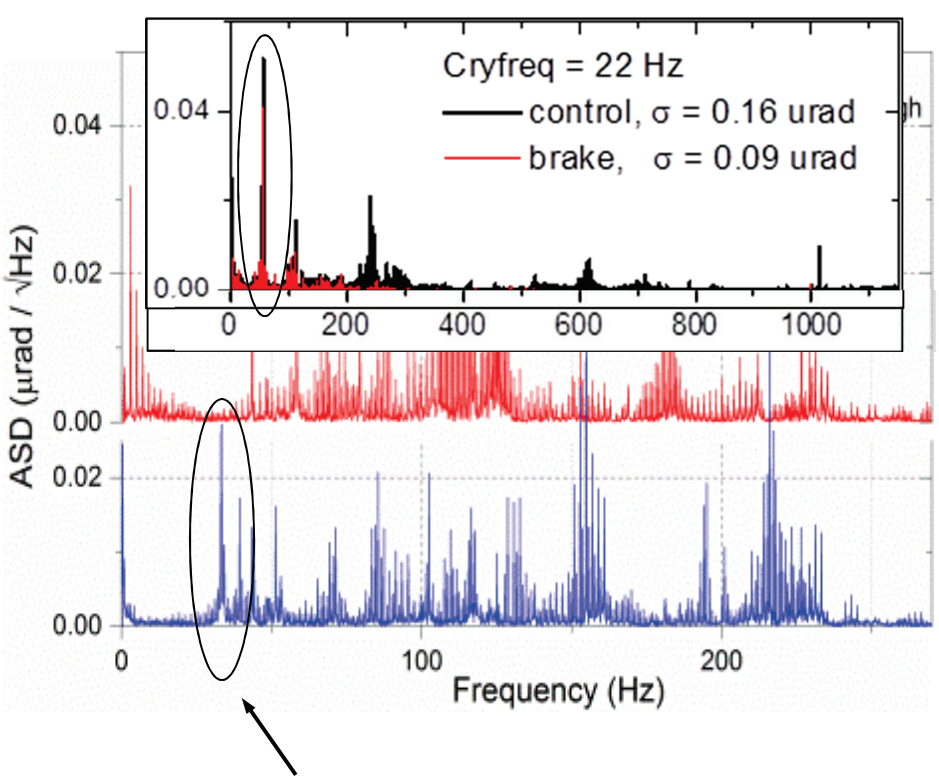
- Analysis of individual components through specific excitation of the natura with the DI
  of components
  y
  disruptions
  es visible



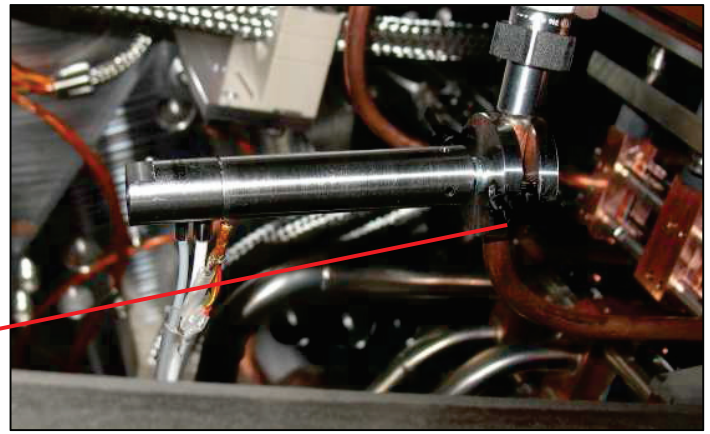


Further Investigations at the DCMs

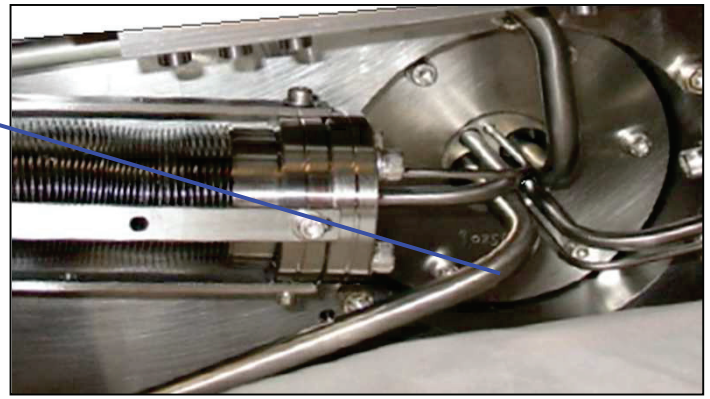
- Combined with the DI it is possible to assign specific frequencies to specific components



Problematic frequency range



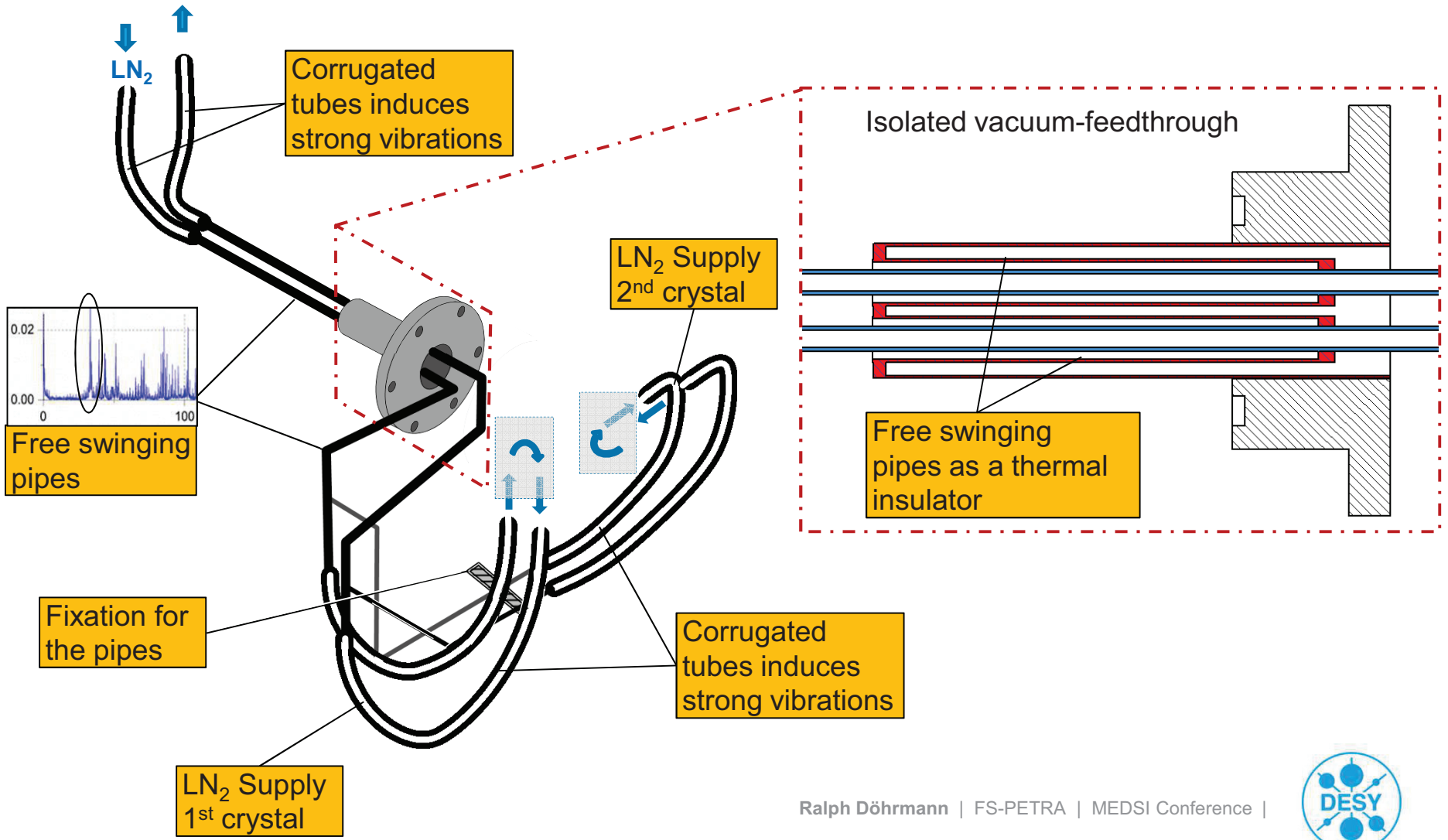
Crystal cage of the 2nd crystal



LN_2 Pipe of cryo-feedthrough

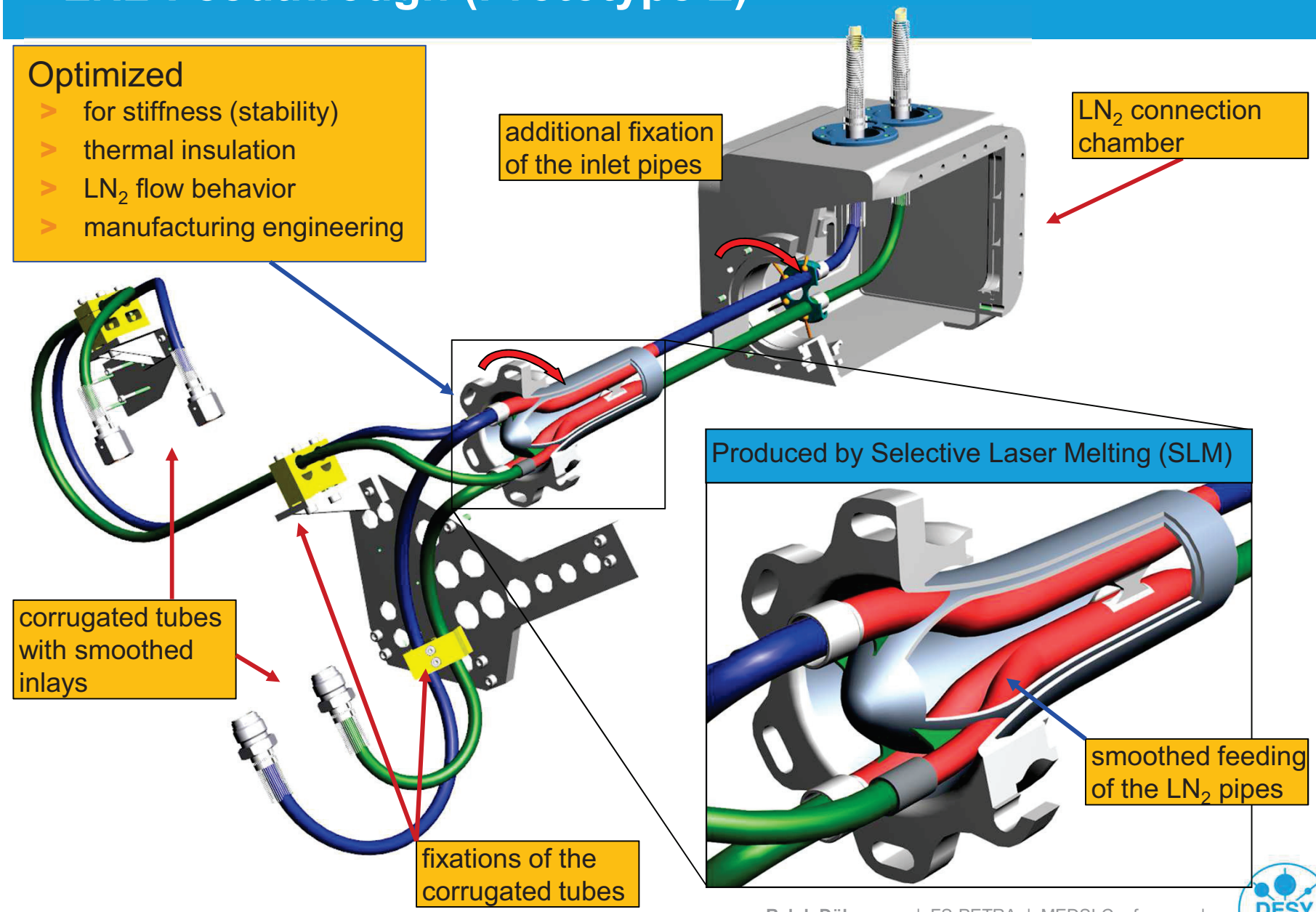
Stability considerations at the installed feedthroughs

> Principle of the original feedthrough with LN_2 transfer system to the crystals (FMB-Oxford)

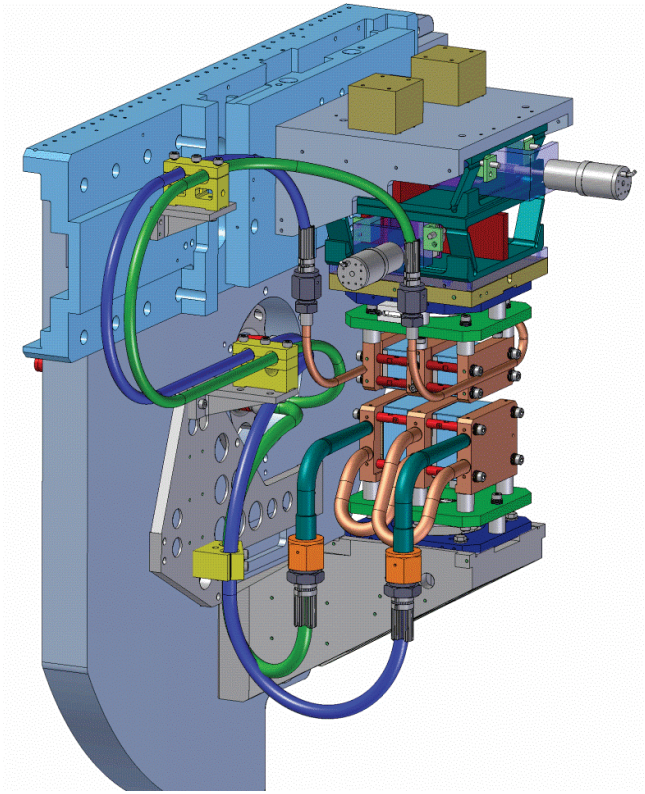


LN2-Feedthrough (Prototype 2)

Optimized
- for stiffness (stability)
- thermal insulation
- LN_2 flow behavior
- manufacturing engineering

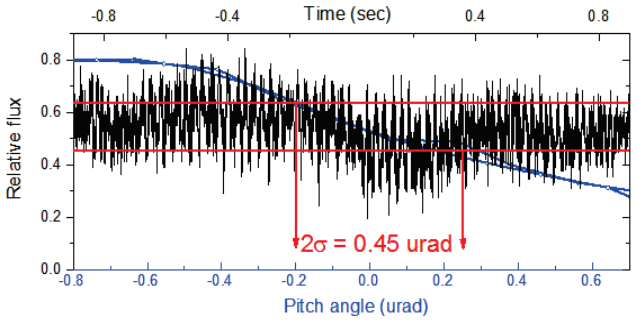


Present state of the DCM after Upgrade

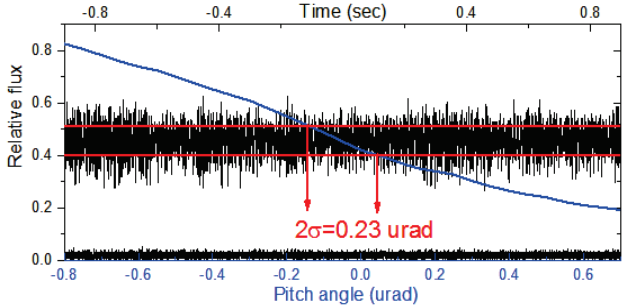


- Improved LN_2 Feedthrough
- Avoidance of long free-swinging components
- All corrugated tubes with inlays
- New routing of the tubes with additional fixation

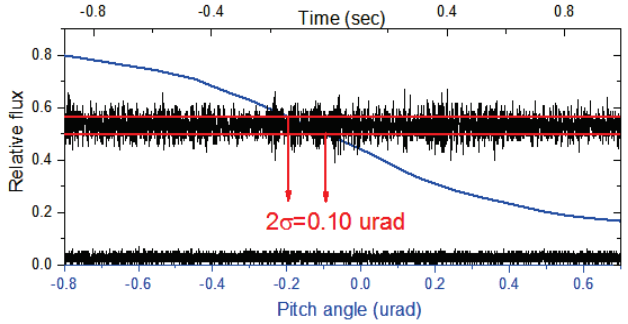
Before upgrade
in control mode
σ = 0,23µrad



After upgrade
control mode
σ = 0,12µrad



After upgrade
brake mode
σ = 0,05µrad



Conclusions

- A “Differential Interferometer” for vibration measurements directly at the DCM-crystals.
- It was shown that the measurements of the DI correspond to those of the measured vibration of the SR-beam
- Two sources of vibrations have been identified:
  - Vibrations due to the LN_2 system
  - Vibrations due to the Bragg axis servo-motor
- Weak points in the mechanical design of the DCM have been identified
- Constructive improvements in DCMs were installed.
- In the best case ~50nrad stability (RMS) has been achieved with the upgraded DCM.

Acknowledgment

Ilya Sergeev

PETRA III Optical group

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DESY Groups

- FS- Workshop
- Central Workshops
- ZM2
- FS-BT

Thank you for your attention